

**DEPARTMENT OF COMMERCE**  

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**UNITED STATES BUREAU OF MINES**  
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**INFORMATION CIRCULAR**

**NITROGEN AND ITS COMPOUNDS**



**BY**

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INFORMATION CIRCULAR  
DEPARTMENT OF COMMERCE - BUREAU OF MINES

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By Bertrand L. Johnson<sup>2</sup>

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## INTRODUCTION

Before 1914, Chile, because of her extensive resources of natural nitrates, practically monopolized the world markets for one of the leading fertilizer materials. Since nitrogen also is an important war material, constituting in fact the principal ingredient in many high-powered explosives, the World War and the widespread insistence upon national self-sufficiency for war materials brought about the development of nitrogen fixation plants in all of the larger countries. The production of by-product ammonia from gas and coke plants was likewise stimulated. As a result, Chile, even after the ocean lanes were reopened, was forced to fight for her lost markets. Since the world capacity to produce is still far in excess of annual consumption, the competition between natural and synthetic supplies has been keen and prices have fallen below pre-war levels.

Chile has recently succeeded in unifying her industry, utilizing the most efficient process now in operation, and the Government is a partner in the new company that will take over all of the present producing companies. These developments place Chilean nitrate of soda in a much more favorable position among the markets of the world. More intense competition will undoubtedly follow and, in order that those interested may become familiar with the fields upon which the nitrogen conflicts of the near future may be waged, the following general summary of the nitrogen industry has been prepared.

## OCCURRENCE OF NITROGEN AND ITS COMPOUNDS

General.— Nitrogen occurs in nature uncombined as a colorless, odorless, and tasteless gas, and combined with other elements in various forms, the chief of which are nitrous and nitric acids and their salts (nitrites and nitrates), ammonia and ammonium compounds, and complex organic nitrogenous compounds in vegetal and animal life and in fossil organic substances such as coal and oil shale.

Nitrogen.— Nitrogen is the predominant element of the air, forming approximately four-fifths of it by volume. It has been estimated by Cameron that the earth's atmosphere contains 4,000,000,000,000,000 tons of nitrogen and Bates states that the air over each square mile of the earth's surface carries 20,000,00 tons of nitrogen, a quantity sufficient to last the world for about 10 years at the present rate of consumption. When the surficial area of the globe, 196,950,00 square miles, is considered the magnitude of this enormous supply can be appreciated.

As nitrogen is slightly soluble in water, it is found dissolved in sea water, river water, rain water, and mineral waters. It also occurs in gases of volcanic origin, in gases from springs and geysers, in gases from inclusions in certain rocks, and in the occluded gases of meteoric iron. It is also reported in small quantities in a variety of rocks and minerals.

Organic nitrogenous compounds in vegetal and animal life.- All living matter contains considerable combined nitrogen which is a necessary constituent for the growth of living organisms. Fossil organic matter, preserved in beds of coal and oil shale, is likewise nitrogenous.

Ammonia and ammonium compounds.- Ammonia and ammonium compounds occur in the soil as a result of the bacterial decomposition of nitrogenous vegetal and animal matter. Ammonia is also present in the air, and some volcanic waters contain ammonium compounds.

Nitrous and nitric acids.- Electrical discharges in the atmosphere cause the formation of oxides of nitrogen. These oxides dissolve in rain to form nitrous and nitric acids which are carried down to the earth's surface and washed into the soil. It has been estimated that lightning results in the fixation of 100,000,000 tons of atmospheric nitrogen annually.

Nitrates.- Deposits of the nitrates of aluminum, ammonium, barium, calcium, copper, iron, magnesium, potassium, and sodium have been reported in various localities. Dana<sup>3</sup> mentions the following nitrates as occurring in nature:

1. Soda niter (Sodium nitrate, Chile saltpeter, cubic niter) .....  $\text{NaNO}_3$
2. Niter (Potassium nitrate, saltpeter) .....  $\text{KNO}_3$
3. Nitrocalcite .....  $\text{Ca}(\text{NO}_3)_2 + n\text{H}_2\text{O}$
4. Nitromagnesite .....  $\text{Mg}(\text{NO}_3)_2 + n\text{H}_2\text{O}$
5. Nitrobarite .....  $\text{Ba}(\text{NO}_3)_2$
6. Gerhardtite .....  $\text{Cu}_4(\text{OH})_6(\text{NO}_3)_2$
7. Darapsite .....  $\text{NaNO}_3 \cdot \text{Na}_2\text{SO}_4 + \text{H}_2\text{O}$
8. Nitroglauuberite .....  $6\text{NaNO}_3 \cdot 2\text{Na}_2\text{SO}_4 + 3\text{H}_2\text{O}$

Gale<sup>4</sup> has summarized the principal characteristics of these minerals as follows:

1. Soda niter, or nitrate of soda (cubic niter), in natural form has the same crystalline form and cleavage as calcite; that is, it is rhombohedral. Composition,  $\text{NaNO}_3$  equals nitrogen pentoxide 63.5 per cent, soda 36.5 per cent. Deflagrates on charcoal with less violence than niter, causing a yellow light. Colors the flame intensely yellow. Is also deliquescent. The pure salt forms transparent, colorless, anhydrous rhombohedra, whose angles closely approximate to right angles, whence its name "cubic niter." It is very soluble in water, and its solubility increases much with increase of temperature, 100 parts of water dissolving about 70 parts at  $0^\circ\text{C}$ ., about 80 parts at  $15^\circ\text{C}$ ., and 125 parts at  $68^\circ\text{C}$ .

3 Dana, E. S., System of Mineralogy: 6th ed., 1892, p. 870.

4 Gale, H. S., Nitrate Deposits; U. S. Geol. Survey Bull. 523, 1912, pp. 7-8.

2. Niter, or potassium nitrate (saltpeter), in crystalline form is orthorhombic. Composition,  $\text{KNO}_3$  equals nitrogen pentoxide 53.5 per cent, potash 46.5 per cent. Occurs naturally as thin white granular crusts or masses or in minute needle-form crystals and as a thin coating on earth, walls, and rocks. Is a transparent crystalline salt with a cooling, rather sharp, saline taste. Deflagrates strongly when thrown on burning coals. Imparts a strong violet color to the flame when color is not masked by the presence of much sodium. Dissolves readily in water and is not altered by exposure.

3. Nitrocalcite, or nitrate of lime (calcium nitrate), occurs in nature in efflorescent silken white or gray tufts and masses and has a sharp and bitter taste. Composition (hydrous calcium nitrate),  $\text{Ca}(\text{NO}_3)_2$  plus  $\text{nH}_2\text{O}$ . On burning coals it slowly fuses with a slight detonation and dries. It is very deliquescent before but not after being desiccated by heat. It occurs in Kentucky in limestone caverns, also in Arizona, and doubtless in many other localities.

4. Nitromagnesite, or nitrate of magnesia, is described as a white salt occurring in efflorescences and having a bitter taste. Composition (hydrous magnesium nitrate),  $\text{Mg}(\text{NO}_3)_2$  plus  $\text{nH}_2\text{O}$ . It is reported to be found in limestone caverns along with nitrocalcite, but its existence as a natural product has not been definitely determined.

5. Nitrobarite, or barium nitrate, occurs in colorless crystals, partly covered with a thin brownish-black coating, resembling wad. Composition,  $\text{Ba}(\text{NO}_3)_2$  equals nitrogen pentoxide 41.4 per cent, baryta 58.6 per cent. It is reported from Chile.

6. Gerhardtite is a basic cupric nitrate, with the composition  $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{Cu}(\text{OH})_2$  equals nitrogen pentoxide 22.5 per cent, cupric oxide 66.2, water 11.3. Crystalline, transparent, with a highly perfect cleavage, yielding thin flexible laminae of a deep emerald-green color and a brilliant vitreous luster. Easily fused, coloring the flame green, and, with soda on charcoal, is easily reduced to metallic copper, with deflagration. Soluble in dilute acids, but insoluble in water. It was first reported from a few specimens found with acicular crystals of malachite in cavities in cuprite at the United Verde copper mines at Jerome, Arizona. Another occurrence in the Clifton-Morenci district, in the same State, is described by Lindgren, specimens having been determined by Hillebrand.

7. Darapskite is a double salt composed of the nitrate and sulphate of sodium. Composition,  $\text{NaNO}_3 \cdot \text{Na}_2\text{SO}_4$  plus  $\text{H}_2\text{O}$  equals nitrogen pentoxide 22.0 per cent, sulphur trioxide 32.7 per cent, soda 38.0 per cent, water 7.3 per cent. Tetragonal, occurring in square tabular crystals, colorless and transparent. The water is readily expelled by heat, without decrepitation. It is reported from the Pampa del Toro in Atacama, Chile, where it is said to be intimately associated with blödite and soda niter.

8. Nitroglauberite occurs as a white, homogeneous mass with fibrous crystalline structure. Composition,  $6\text{NaNO}_3 \cdot 2\text{Na}_2\text{SO}_4$  plus  $3\text{H}_2\text{O}$  equals sodium nitrate 60.1 per cent, sodium sulphate 33.5 per cent, water 6.4 per cent. Soluble in water. Occurs in the desert of Atacama, Chile.

Of these various nitrates only the sodium nitrate and the potassium nitrate are commercially important. The others are of interest mineralogically only.

Sodium and potassium nitrates are found in fertile soils in all parts of the world but occur in concentrated deposits only in extremely dry desert regions and are recoverable as nitrate salts only from the latter type of occurrence. They are also formed in small more or less concentrated deposits; the so-called cave niter deposits. Included also under the term "cave niter deposits" are those deposits of nitrates found in protected portions of fractured or cavernous ledges or under overhanging ledges; however, the material did not necessarily originate in a cave.

The largest known nitrate deposits occur in northern Chile. These are predominantly of sodium nitrate; however, considerable potassium nitrate occurs in parts of the same region. Deposits of sodium nitrate also occur in Egypt, Argentine Republic, Colombia, Southwest Africa Protectorate, Mexico, and the United States. Deposits of potassium nitrate are reported from India, Bolivia, Central Australia, Russia, Canada, Union of South Africa, and the United States.

#### USES OF NITROGEN AND ITS COMPOUNDS

General.— The basic nitrogenous materials - atmospheric nitrogen, natural nitrate deposits, coal, oil shale, and various organic nitrogenous materials - are utilized in the preparation of a very limited number of primary nitrogenous products or compounds, but these in turn are converted into a large number of nitrogen-bearing substances of diverse uses.

The initial products obtained from the basic sources of nitrogen supply include nitric acid, ammonia, hydrocyanic acid, cyanamide, potassium nitrate, and sodium nitrate. Fixation of atmospheric nitrogen produces nitric acid, ammonia, or cyanamide. The destructive distillation of coal yields ammonia and hydrocyanic acid. Natural nitrate deposits furnish sodium nitrate and potassium nitrate. The availability of the various organic materials as sources of nitrogen is practically limited to their use as fertilizers and feeding stuffs. The waste from beet sugar operations, however, is utilized for the production of sodium cyanide.

Nitric acid and nitrates.— Nitric acid is of great industrial importance as an intermediary in the production of other substances. It is thus used in the nitration of various organic compounds. The nitration of the hydrocarbons resulting from the destructive distillation of coal tar (benzene, naphthalene, and anthracene) yields the bases for a wide assortment of dyes. Nitrobenzene is the foundation of the aniline dye industry. It is also used as a soap perfume (oil of mirbane). The nitrated products of the benzene series (benzene, toluene, and xylene) also furnish important explosives such as trinitrobenzene, trinitrotoluene

(T.N.T.), and picric acid. The nitration of cellulose yields nitrocellulose, which is variously converted into smokeless powders, gelatin dynamites, collodion, pyroxylin plastics (celluloid, xylonite), rayon (artificial silk), artificial leather, photographic films, lacquers, enamels, varnishes, and bronzing liquids. The nitration of glycerin yields nitroglycerin, the base of ordinary dynamite, and the nitration of starch gives another explosive, nitrostarch.

Nitric acid is used also in the preparation of various nitrates, such as sodium nitrate, potassium nitrate, barium nitrate, strontium nitrate, calcium nitrate, silver nitrate, ammonium nitrate, and ferric nitrate.

Sodium nitrate, which is obtained naturally from the Chilean deposits and also synthetically, is used chiefly as a fertilizer. It is likewise used in blasting powders, fireworks, and in the manufacture of sulphuric acid, nitric acid, red lead, glass, potassium nitrate, sodium arsenate, calcium nitrate, and sodium nitrite. Potassium nitrate is used as a fertilizer, in glass making, in gunpowder, for pickling and salting meat, in the manufacture of sulphuric acid, in fireworks, as a chemical reagent, and in medicine. Barium nitrate is used in the manufacture of explosives, fireworks, and barium peroxide, which in turn is used in the making of hydrogen peroxide. Strontium nitrate is used in fireworks. Calcium nitrate is used as a fertilizer and in the manufacture of barium nitrate, ammonium nitrate, and lamp filaments. Silver nitrate is used in indelible inks, in photography, in silvering mirrors, and in medicine. Ammonium nitrate is used as a fertilizer, in explosives (including "safety explosives"), and as a source of nitrous oxide ("laughing gas"). A basic ferric nitrate is used in silk dyeing and weighting and for coloring buff on cotton. Sodium nitrite and nitrous acid are used in dye making.

Nitric acid is also used as a solvent, as a chemical reagent, as a bleaching agent in silk production, as a source of nitric oxide in the manufacture of sulphuric acid, and in the manufacture of fulminate of mercury which is used as a primer or detonator of other explosives.

Ammonia and ammonium compounds.—Ammonia is undoubtedly used most as the nitrogen carrier in various fertilizer salts. Those of immediate concern for this purpose (and from which various other combinations can be prepared) are ammonium sulphate, ammonium nitrate, and ammonium phosphate. Ammonium sulphate is the principal form in which nitrogen, fixed in the form of ammonia, is marketed for fertilizer purposes. It is usually made by passing ammonia gas into sulphuric acid, but it is also made in small quantities by treating gypsum (calcium sulphate) with water, ammonia, and carbon dioxide. To a limited extent it has also been produced from cyanamide. Monoammonium phosphate, produced by the absorption of ammonia gas in phosphoric acid, is used as a fertilizer. Ammonium nitrate is produced by the neutralization of ammonia and nitric acid, by the double decomposition of sodium nitrate and ammonium sulphate, or by the action of ammonia and carbon dioxide on calcium nitrate. Double salts of ammonium nitrate and ammonium sulphate are also manufactured for use as fertilizers, as are likewise mixed salts obtained by double decomposition of ammonium nitrate with potassium chloride and with potassium sulphate. In the production of super-phosphate ammonia liquor is now added directly to the batch in the mixing pan in the correct proportions required to neutralize the free acid in the superphosphate.

Ammonia and its compounds have many other uses besides as fertilizers, however. Ammonia is largely used for refrigeration purposes, as a chemical reagent, and for household purposes. It is converted by oxidation to nitric acid. It is also used in the preparation of cuprammonium artificial silks, with ammonium chloride in the preparation of auramine dykes, and in the preparation of cyanides. Sodamide, important in the synthesis of indigo, is made by the action of dry ammonia on metallic sodium. An ammonia solution is used in the treatment of cotton goods preliminary to the use of mordant dyes. In the nitriding or nitrogenization process for case-hardening steels special alloy steels are subjected to the action of ammonia gas at elevated temperatures. Anhydrous ammonia is now used as a source of nitrogen and hydrogen which are obtained by cracking the ammonia; cracked ammonia may be used in all of the standard kinds of welding. Ammonia is also used in combination with chlorine in water purification, as a raw material in organic syntheses, and for neutralizing traces of acid in refined oil.

Ammonium chloride is used in medicine, soldering, tinning, dyeing, calico printing, dry-battery manufacture, and in galvanizing iron. Ammonium sulphate, besides being used as a fertilizer, is used as a base for making other ammonium salts and for fireproofing fabrics. Redistilled with lime it yields ammonia which is dissolved in water as aqua ammonia. The electrolysis of a water solution of ammonium sulphate containing sulphuric acid yields ammonium persulphate, useful as an oxidizer for many minor purposes, as a solvent for silver in photography, and in making hydrogen peroxide. Ammonium bicarbonate is an intermediate product in the manufacture of sodium carbonate by the Solvay process. Both ammonium carbonate and ammonium bicarbonate are used in baking, wool scouring, dyeing, and as a constituent of smelling salts. Ammonium nitrate and ammonium picrate are used in explosives. Ammonium nitrate, as previously noted, is also used in the preparation of nitrous oxide ("laughing gas"). Urea, made from ammonia and carbon dioxide, is used in the preparation of celluloid products.

Cyanamide is used chiefly as a fertilizer, applied either alone or in commercial mixed fertilizers, but considerable of it is converted into various chemicals for industrial or agricultural uses. These chemicals include ammonia, sodium cyanide, dicyandiamide, urea, guanidine, and nitroguanidine. By far the largest amount is changed into ammonia. Dicyandiamide is used for making organic dyes and for reducing the temperature of combustion of explosives.

Cyanogen is obtained from the gases resulting from the destructive distillation of coal and beet sugar waste. It is driven off as hydrocyanic acid but is recovered as ferrocyanides, sulphocyanides, or cyanides. In the United States, owing to commercial conditions, this recovery is usually not considered profitable and is neglected. Sodium cyanide, potassium cyanide, sodium ferrocyanide, potassium ferrocyanide, calcium ferrocyanide, ammonium sulphocyanide, ferric ferrocyanide, potassium ferricyanide, and sodium sulphocyanide are some of the cyanogen compounds produced.

Sodium and potassium cyanides are used in the cyanide process of gold and silver recovery. Potassium cyanide is used in the preparation of synthetic indigo, in photography, and in electroplating. Sodium cyanide is used in the preparation of hydrocyanic acid and in the preparation of the tear gas, cyanogen chloride. Sodium and potassium ferrocyanides are used in the preparation of ferric ferrocyanide (Prussian blue), which is used in dyeing, painting, and printing. Potassium ferricyanide is said to be used also in blue printing and dyeing. The sulphocyanides, the ferrocyanides, and the ferricyanides are all utilized in the making of cyanides. Hydrocyanic acid gas, because of its poisonous nature, is used in fumigating. Cyanogen compounds are very effective carburizing agents, and potassium cyanide and potassium ferrocyanide are used in the casehardening of steel.

#### MINING AND TREATMENT OF NATURAL SODIUM NITRATE

Bain and Mulliken<sup>5</sup> have described the mining and treatment of the Chilean nitrate as follows:

The fact that the nitrate is found in thin, irregular patches at or near the surface leads naturally and properly to open-cut mining.\* \*

Where the area of any patch is sufficiently extensive and the grade of caliche is consistently high enough to permit regular working, the ground is opened by trenches. These are carried forward laterally across the ground to be mined, the caliche and overburden being drilled and blasted ahead of the trench, broken, and hand sorted in it, the waste rock piled back of the trench with the caliche on top, and finally the caliche hauled from there to the crushers along temporary narrow-gage railway lines connecting with main field lines ramifying over the property. When the patches are too small or the grade too irregular the material is won by the older style of mining, which involves working small pits from which the nitrate is collected by carts.

Formerly all the drilling and blasting was done entirely by hand, and carts were used to bring all the nitrate to the main field lines. Now, at many of the properties, air drills have been introduced for breaking up the big blocks, and efforts are being made to use them in the first breaking up of the ground as well. At present the latter work is still accomplished at most oficinas by putting down with hand jump drills and small "pop" shots a hole 6 to 8 inches in diameter, chambering it below the nitrate bed, and blasting with some 300 or more pounds of a cheap slow-burning black powder made locally. Since the effect of such a shot is to heave the ground up in blocks of as much as 12 feet in diameter, the necessity of secondary blasting is evident. It is not the purpose of the mining to break the rock fine, as this increases the loss. The large blocks are broken with 25-pound sledges and the caliche separated from the barren rock by hand sorting in the pit.

5 Bain, H. F., and Mulliken, H. S., The Cost of Chilean Nitrate: U. S. Dept. of Commerce, Supplement to Commerce Repts., Trade Information Bulletin No. 170, Nitrogen Survey, pt. I, 1924.

\* \* \* In special cases drag-line scrapers and steam shovels have been introduced. \* \* \*

Transportation of the caliche to the treatment plant is by field railway lines of various gages. In part carts are still used, but now rarely except to gather caliche mined in small patches or from outlying parts of the property. There is a distinct trend away from carts and toward direct loading. There is a further tendency toward larger central treatment plants drawing caliche from greater distances and the use of heavier locomotives and rolling stock. Formerly haulage of one-half mile to a mile and a half was the usual limit. Now caliche is hauled as much as 25 miles in heavy trains of 15-ton cars running on well-built main lines. When necessary, caliche is brought to the main lines over temporary 60-centimeter tracks in 7-ton side-dump horse-drawn cars.

\* \* \* With the exception of one plant, all those in the nitrate region that are in regular operation are built for the Shanks process. At the Delaware Oficina of the Du Pont Nitrate Co., a modification of this, designed by Mr. A. W. Allen and known as the Allen process, has now been in successful use for more than a year. \* \* \*

Essentially the Shanks process is one of treatment of coarse crushed rock by countercurrent leaching, the aqueous solution being brought up in strength and temperature to boiling point, decanted, cooled, and returned for reuse. The caliche contains a number of water-soluble salts; of which sodium nitrate and sodium chloride are most important. It happens that the solubility of sodium nitrate increases with rise of temperature at a much higher rate than does that of sodium chloride. Indeed, at the higher temperatures involved, the solution in the presence of caliche will precipitate sodium chloride and take up additional nitrate. The nitrate rich solution is then drawn off, clarified, and allowed to cool. As the temperature falls nitrate crystallizes out, the other salts being retained in solution. The excess solution is drawn off, the nitrate drained or put through centrifugals, and the liquor sent back for reuse. These are the essentials of the process; but there are many minor complications and side processes such as those involved in precipitating "high potassium" nitrate, "96 per cent" nitrate, "98 per cent" nitrate, recovery of iodine as a by-product, hastening precipitation, recovery of heat, and other similar matters. In general, however, the plants are operated to produce the standard "95 per cent" nitrate with the minimum of loss in the refuse\* \* \* and the highest speed of treatment (to secure plant capacity) consistent with making acceptable recoveries.

Since the above description was written a new process, known as the "Guggenheim process," has been perfected and put in operation on a large scale at certain plants. No details are available regarding this process, but it is reported to recover 90 per cent of the nitrate from the caliche as compared with 55 per cent under the older Shanks method; also, it permits the treatment of ore averaging as little as 8 per cent of sodium nitrate as compared with a minimum of 15 per cent necessary with the old process.

## FIXATION OF ATMOSPHERIC NITROGEN

General.- To render atmospheric nitrogen available for commercial purposes it must be combined with other elements or made into "fixed nitrogen" as it is called. The problem of nitrogen fixation on a commercial basis has been solved in three distinct ways: (1) By the Arc process, (2) the Cyanamide process, and (3) the Direct Synthetic Ammonia process. In the Arc process the existing air mixture is used, the only pretreatment of the air consisting of the removal of the carbon dioxide and water vapor ingredients. In the other two processes, it is first necessary to effect the isolation of the nitrogen component from the other ingredients, in other words, to remove the oxygen as well as the water vapor and carbon dioxide. Only the arc process produces nitric acid directly; the other processes give ammonia or calcium cyanamide as their names indicate.

Arc process.- In the arc process the basis of the chemical change is the partial conversion at high temperatures of nitrogen and oxygen to form nitric oxide. Air is passed rapidly through a zone of exceedingly high temperature produced in an electric arc furnace. Nitric oxide,  $\text{NO}$ , is produced, which on cooling in the presence of the accompanying oxygen forms nitrogen dioxide,  $\text{NO}_2$ . The nitrogen dioxide produced is absorbed in water, giving dilute nitric acid.

Cyanamide process.- In the cyanamide process nitrogen is fixed by bringing it in contact with finely powdered calcium carbide heated to  $1,000^\circ \text{C}$ . Calcium cyanamide,  $\text{CaCN}_2$ , is formed.

Direct synthetic ammonia process.- The direct synthetic ammonia process accomplishes the direct synthesis of ammonia,  $\text{NH}_3$ , from nitrogen and hydrogen by passing a compressed mixture of these two gases over a catalyst at high temperature. Iron oxide is said to be the best catalyst base known at present. The gas coming off is a mixture of nitrogen, hydrogen, and ammonia, from which the ammonia is removed by absorption or refrigeration, and the other gases are returned to the catalyst for further ammonia formation. There are a number of methods of operation of the direct synthetic ammonia process, which have come to be called processes. These include the Haber-Bosch, Claude, Casale, Fauser, and other processes. In all of these various methods, however, nitrogen is fixed with hydrogen in the presence of a catalyst.

## BY-PRODUCT NITROGEN

In the coking of coal the nitrogen contained in the original coal becomes distributed between the coke, the tar, and the gas. The only portion valuable for its nitrogen content is the gas, in which the nitrogen occurs chiefly as ammonia. This ammonia is recovered by washing with water or with sulphuric acid and forms either ammonia liquor or the compound ammonium sulphate, according to which of the two liquids is used as the washing agent.

## WORLD NITROGEN INDUSTRY

General.— The outstanding features in the world situation are (1) the rapidly increasing world production of nitrogen, due partly to the desire of the major nations to become self-sufficient in nitrogen; (2) a less rapid increase in the consumption of nitrogen; and consequently, (3) over-supplied world markets and declining prices for nitrogen.

As a result of the rapid development of the synthetic nitrogen industry, there was keen competition in the world markets not only among the synthetic products but also between the synthetically produced nitrogen products and the natural nitrates from Chile which for many years had had a monopoly of the world's markets. This competition has led to national and international understandings among the producers as to prices and market quotas. The first of these agreements was between certain German producers (including the I. G. Farbenindustrie) of the synthetic nitrogen products. Later, agreements were made by this syndicate with Norwegian, British, and Italian producers. Finally, in the summer of 1929, with a view to avoiding a ruinous price war, an agreement was reached between the German syndicate, the Imperial Chemical Industries of Great Britain, and the Chilean producers (the parties having a reported combined representation of about 70 per cent of the world's production of nitrogen-bearing products) regarding the production and marketing of nitrogen compounds in world markets exclusive of the United States. Early in August, 1930, a new synthetic nitrogen cartel was formed in Europe, the chief members of which were Great Britain, France, Germany, Belgium, Italy, Sweden, Poland, and Czechoslovakia; and, a few days later, the German Synthetic Nitrate Syndicate, acting on behalf of all of the above European producers of the synthetic product, signed an agreement with the Chilean natural nitrate interests as to the price level to be maintained in all parts of the world with except the United States, the agreement to run for one year.

Statistics regarding the production, imports, exports, and apparent consumption of nitrogen for various countries, as well as for the world, in the calendar year 1928, are given in the following table:

World nitrogen statistics for the year ended  
December 31, 1928

(In thousands of short tons of nitrogen)

| Country              | Production | Imports | Exports | Apparent consumption |
|----------------------|------------|---------|---------|----------------------|
| Germany .....        | 870.0      | 20.8    | 316.5   | 574.3                |
| United States .....  | 193.0      | 268.6   | 35.4    | 431.2                |
| France .....         | 70.0       | 110.5   | 7.2     | 173.3                |
| Japan .....          | 73.6       | 78.8    | 7.3     | 145.1                |
| Belgium .....        | 50.4       | 50.4    | 6.2     | 94.6                 |
| Netherlands .....    | 11.1       | 81.8    | 11.5    | 81.4                 |
| United Kingdom ..... | 156.0      | 18.0    | 98.2    | 75.8                 |
| Italy .....          | 55.6       | 24.9    | 4.9     | 75.6                 |

World nitrogen statistics for the year ended Dec. 31, 1928<sup>1</sup>--(Cont'd)

(In thousands of short tons of nitrogen)

| Country                                    | Production | Imports | Exports | Apparent consumption |
|--------------------------------------------|------------|---------|---------|----------------------|
| Spain .....                                | 8.2        | 56.1    | - -     | 64.3                 |
| Poland .....                               | 45.5       | 21.3    | 4.3     | 62.5                 |
| Denmark .....                              | - -        | 34.9    | - -     | 34.9                 |
| Egypt .....                                | - -        | 34.7    | - -     | 34.7                 |
| China .....                                | 2.0        | 33.8    | 2.1     | 33.7                 |
| Dutch East Indies..                        | - -        | 31.4    | - -     | 31.4                 |
| Java .....                                 | - -        | 28.4    | - -     | 28.4                 |
| Czechoslovakia ....                        | 14.7       | 12.0    | .9      | 25.8                 |
| Sweden .....                               | 7.2        | 13.2    | .2      | 20.2                 |
| Canada .....                               | 42.9       | 9.5     | 35.4    | 17.0                 |
| Formosa .....                              | - -        | 16.8    | - -     | 16.8                 |
| U. S. S. R. ....                           | 7.1        | 3.5     | - -     | 10.6                 |
| Hawaiian Islands ..                        | - -        | 10.2    | - -     | 10.2                 |
| Korea .....                                | - -        | 6.7     | - -     | 6.7                  |
| Jugo Slavia .....                          | 16.8       | .9      | 11.2    | 6.5                  |
| India and Ceylon ..                        | 3.4        | 4.8     | 2.2     | 6.0                  |
| Philippine Islands..                       | - -        | 5.8     | - -     | 5.8                  |
| Irish Free State ..                        | .3         | 4.7     | .2      | 4.8                  |
| Hungary .....                              | .2         | 4.4     | - -     | 4.6                  |
| British West Indies                        | - -        | 4.6     | - -     | 4.6                  |
| New Zealand .....                          | - -        | 4.4     | - -     | 4.4                  |
| Cuba .....                                 | - -        | 3.4     | - -     | 3.4                  |
| Canary Islands ....                        | - -        | 3.4     | - -     | 3.4                  |
| South Africa .....                         | - -        | 3.1     | - -     | 3.1                  |
| Australia .....                            | 4.0        | - -     | 1.0     | 3.0                  |
| Finland .....                              | - -        | 2.7     | - -     | 2.7                  |
| Austria .....                              | - -        | 3.8     | 1.6     | 2.2                  |
| Norway .....                               | 45.6       | - -     | 43.5    | 2.1                  |
| Greece .....                               | - -        | 1.5     | - -     | 1.5                  |
| French West Africa..                       | - -        | 1.1     | - -     | 1.1                  |
| East Coast Sumatra..                       | - -        | 1.0     | - -     | 1.0                  |
| Peru .....                                 | - -        | 1.0     | - -     | 1.0                  |
| Brazil .....                               | - -        | .7      | - -     | .7                   |
| Fiji .....                                 | - -        | .6      | - -     | .6                   |
| West Indies (except<br>Cuba and Bermuda).. | - -        | .3      | - -     | .3                   |
| Estonia .....                              | - -        | .3      | - -     | .3                   |
| Latvia .....                               | - -        | .3      | - -     | .3                   |
| Newfoundland .....                         | - -        | .2      | - -     | .2                   |
| Argentina .....                            | - -        | .2      | - -     | .2                   |
| Barbados .....                             | - -        | .1      | - -     | .1                   |
| Bulgaria .....                             | - -        | .1      | - -     | .1                   |
| Switzerland .....                          | 7.8        | 1.5     | 9.3     | .0                   |
| Chile .....                                | 553.0      | .0      | 489.0   | 2/ .0                |
| Manchuria .....                            | - -        | - -     | - -     | - -                  |
| Mexico .....                               | - -        | - -     | - -     | - -                  |
| Totals .....                               | 2,243.4    | 1,021.2 | 1,088.1 | 2,112.5              |

1 Data compiled for Chem. and Met. Eng. by Messrs. H. P. Emerson and E. T. Dunn of the DuPont Ammonia Corporation of Wilmington, Del. Published in Chem. and Met. Eng., vol. 37, No. 1, Jan. 1930, pp. 6-7.

2 Stocks on hand Dec. 31, in Chile were equivalent to 161,000 short tons of nitrogen.

**Note:** In computing apparent consumption, stocks on hand are not taken into account. The consumption of nitrogen in Germany is probably somewhat less than that indicated because of the large stocks of ammonium sulphate. Furthermore, there were unconsumed stocks of Chile nitrate in numerous countries on Dec. 31, 1928.

World production. - As recently as the beginning of the present century the world was dependent for its supplies of "chemical nitrogen" - that is, nitrogen from sources other than nitrogenous farm, city, and industrial organic wastes - upon the natural sodium nitrates from Chile; the potassium nitrates from India and certain other tropical countries; and the nitrogen-bearing compounds obtained as by-products in various industrial works, such as coal-gas plants, producer-gas works, and oil-shale distillation plants. Of the nearly 300,000 tons of nitrogen contained in these various substances, about two-thirds were in the natural sodium nitrate from Chile (exports of 1,462,956 metric tons of sodium nitrate in 1900) and about one-third in the ammoniacal by-products of various industries (about half a million tons of ammonium sulphate, or the equivalent). Perhaps 1 per cent was contained in potassium nitrate. Chile furnished almost the entire production of sodium nitrate and India, practically all of the potassium nitrate. Nearly half of the by-product ammonium sulphate (or the equivalent) came from the United Kingdom and almost a fourth from Germany.

In the years preceding the world War the annual world production of nitrogen increased rather gradually to over 800,000 tons in 1913. Chilean sodium nitrate maintained its lead (production increasing to 2,772,254 metric tons in 1913), but as a result of the increase of by-product nitrogen and the introduction of nitrogen fixation, its proportion of the total world nitrogen production had declined to only a little over 50 per cent. By-product nitrogen production showed a marked increase, the production of ammonium sulphate (or the equivalent) reaching about a million and a half tons in 1913. Fixation of atmospheric nitrogen started in 1903 with the commercial application of the arc process. This was followed, in 1905, by the cyanamide process and, in 1913, by the direct synthesis of ammonia from atmospheric nitrogen. The pure nitrogen content of the nitrogenous products, principally cyanamide, produced from the fixation of atmospheric nitrogen formed in 1913 about 10 per cent of the total nitrogen production of that year.

The World War, because of the tremendous military demand for explosives, exerted a profound influence upon the industry. In the early years of the war, world production declined considerably owing to the shutting off of shipments of Chilean nitrate to the Central European Powers and to the interference of German raiders with the shipments from Chile to the Allied Powers. Later, however, production of Chilean nitrate reached new high levels; and this increase, combined with the steady growth of by-product nitrogen production and the great increase in fixed nitrogen production, carried the total production of the world in terms of pure nitrogen to a record level of around 1,500,000 tons in 1917. The War proved a great stimulus to the fixed nitrogen industry, largely owing to the needs of the Central Powers, who were cut off from the supply of natural nitrates from Chile, and at the end of the War the annual producing capacity operating or building was around 720,000 tons of nitrogen. By far the largest increase was in cyanamide production; production by the direct synthetic ammonia process also increased but more slowly. Production by the arc process gained little.

With the end of the war cessation of munitions' demands caused an accumulation of stocks and a curtailment of output. Military requirements had increased production to a point far in excess of the normal rate of expansion of peace-time needs. World production soon fell to around 1,000,000 tons of nitrogen a year, but by 1925 it started to rise again and, except for 1927, when a sharp decline in the Chilean production caused a decrease in the world total, continued to advance steadily to over 2,000,000 tons annually. The present output is more than seven times the 1900 production and two and one-half times the 1913 production. The total world production in terms of pure nitrogen for recent years is given in Figure 1 and in the following table:

World production in terms of pure nitrogen  
in metric tons for years ended May 31

(British Sulphate of Ammonia Federation, Ltd.)

|           |           |
|-----------|-----------|
| 1923 - 24 | 1,057,500 |
| 1924 - 25 | 1,154,300 |
| 1925 - 26 | 1,333,700 |
| 1926 - 27 | 1,264,500 |
| 1927 - 28 | 1,724,000 |
| 1928 - 29 | 2,113,000 |

Fixed nitrogen now dominates the nitrogen industry. In the year ended May 31, 1929, only 23 per cent of the world's inorganic nitrogen consumption was furnished by natural sodium nitrate and only 20 per cent by by-product sources, while atmospheric nitrogen fixation processes supplied the balance of a little over 56 per cent or 1,200,000 metric tons. The period following the War favored the development of the direct synthetic ammonia process; and, of the nitrogen now produced by the fixation of atmospheric nitrogen (56 per cent of the total), near three-fourths is fixed by the direct synthetic ammonia process, while less than one-fourth is fixed by the cyanamide process and less than 5 per cent by the arc process.

In 1928, the five largest nitrogen producing countries, Germany, Chile, United States, Great Britain, and France, accounted for about 86 per cent of the world production of nitrogen. Germany is by far the largest producer; the larger part of her nitrogen comes from synthetic processes although her by-product nitrogen production exceeds that of all other countries except the United States. Chile, because of her sodium nitrate industry, ranks second. The United States and Great Britain are third and fourth respectively, largely because of their by-product coke industries.

World consumption.— The world consumption of nitrogen is increasing. The annual increase in recent years has been irregular but has had a general upward trend and has ranged from 90,000 to 360,000 tons. The total world consumption of inorganic nitrogen, as estimated by the British Sulphate of Ammonia Federation, Ltd., is shown in the following table:

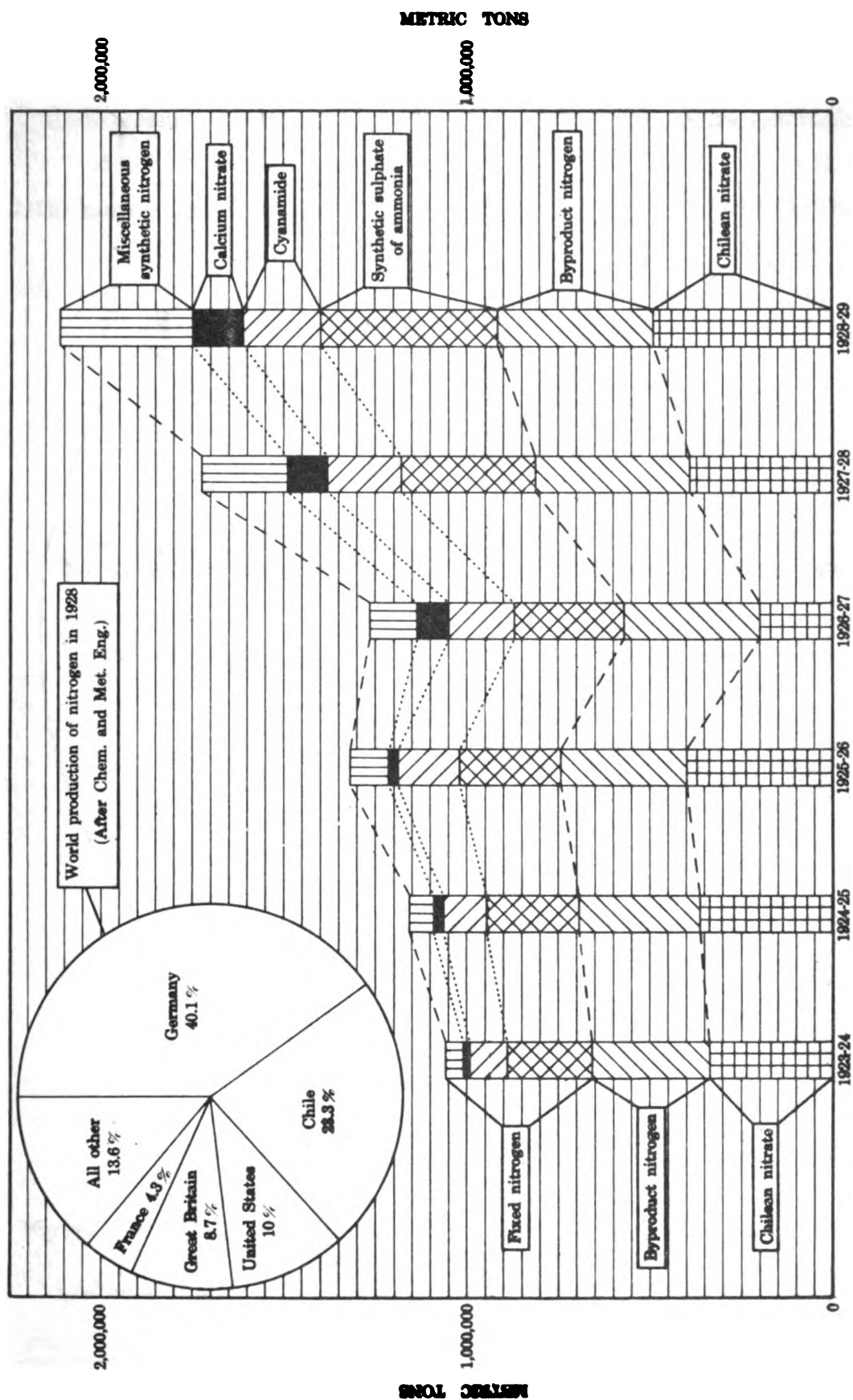


Figure 1. - World production of nitrogen, in metric tons of pure nitrogen, for years ending May 31  
(After statistics of the British Sulphate of Ammonia Federation, Ltd.)

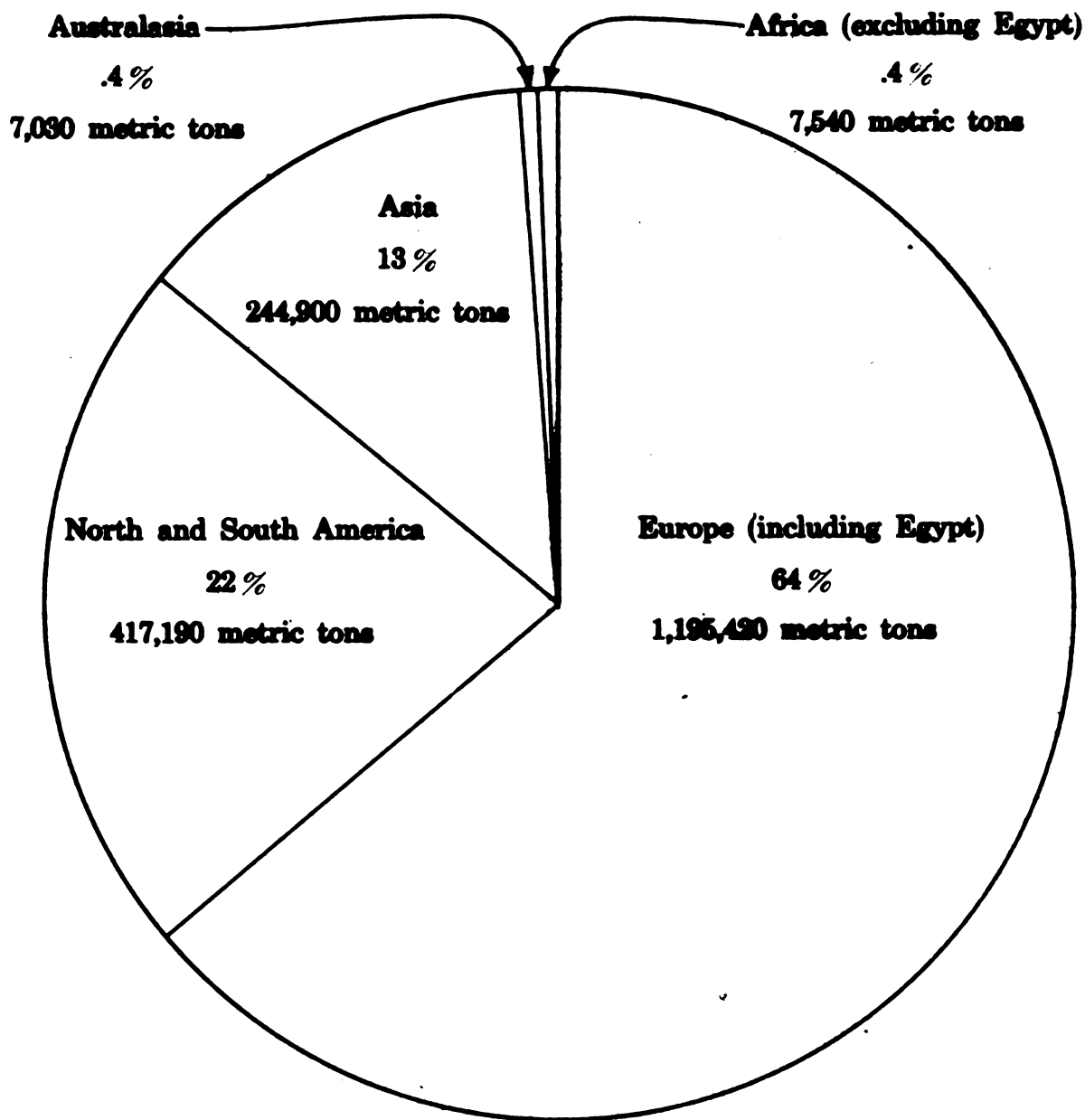


**Figure 2. — World consumption of nitrogen, in metric tons of pure nitrogen,  
for year ending May 31, 1929  
(After statistics of the British Sulphate of Ammonia Federation, Ltd.)**

## World consumption of nitrogen in metric tons of pure nitrogen

(British Sulphate of Ammonia Federation, Ltd.)

| Year ended<br>May 31 | Chilean nitrate<br>of soda | Manufactured<br>nitrogen | Total     | Agricultural<br>consumption |
|----------------------|----------------------------|--------------------------|-----------|-----------------------------|
| 1924                 | 340,000                    | 719,000                  | 1,059,000 | 934,000                     |
| 1925                 | 363,000                    | 786,800                  | 1,149,800 | 1,020,000                   |
| 1926                 | 324,200                    | 934,300                  | 1,258,500 | 1,117,000                   |
| 1927                 | 275,200                    | 1,037,500                | 1,312,700 | 1,200,000                   |
| 1928                 | 391,300                    | 1,250,700                | 1,642,000 | 1,490,000                   |
| 1929                 | 419,000                    | 1,453,000                | 1,872,000 | 1,684,000                   |

Sixty-four per cent of the world's consumption of nitrogen is used in Europe and 85 per cent of the European consumption is used in the countries of Central and Northern Europe. The Americas rank second as a nitrogen consuming region, with the largest consumption in the United States. Asia, ranking third as a consumer of nitrogen, is the only other large consuming area. The relative importance of these various regions as consumers of inorganic nitrogen is shown in Figure 2.

Opinions vary as to the relative amount of nitrogen destined for agricultural uses, the estimates ranging from 60 to 90 per cent of the total nitrogen consumption. The British Sulphate of Ammonia Federation, Ltd., considers that for the world the amount so used is about 90 per cent. In the United States the proportion (as estimated by others) is somewhat lower than in the rest of the world, and is probably only 60 to 75 per cent of the total. Estimates of industrial requirements range accordingly from 10 to 40 per cent of the total nitrogen consumption.

## NITROGEN INDUSTRY OF THE UNITED STATES

Nitrate deposits.—None of the deposits of nitrates in the United States appear to be large enough for commercial development. Nitrates occur in the various limestone caverns of the Southeastern States, and during the Civil War some of these deposits were worked for potassium nitrate for use in making gunpowder. These deposits are usually small, low-grade, and probably of little economic value under existing conditions. Other cave niter deposits occur in many of the Western States but nowhere in commercial quantities.

Large deposits of nitrate-bearing earths or clays have been found in several of the Western States, particularly in southeastern California, which contain 2 to 6 per cent of sodium nitrate in places. These deposits, however, are of doubtful commercial importance under present conditions because of their limited extent, low nitrate content, and mode of occurrence. The deposits in the Amargosa River Valley in southeastern California are, so far as known, the most extensive and probably the richest of this type as yet recorded in the United States. The principal nitrate deposits of this region are associated with the outcrops of Tertiary clays. The saline layer (called caliche locally) is a blanket deposit

usually less than 6 inches thick overlying the bedrock parallel to the surface of the ground and overlain in turn usually by less than a foot of soil. The caliche is essentially bedrock which has become disintegrated by weathering and then has been cemented to varying degrees of consolidation by various salts. The average nitrate content of even the best material is low, few samples carrying over 5½ per cent of sodium nitrate.

Domestic production.— Most of the nitrogen produced in the United States has been derived from by-product sources, but since 1921 the synthetic nitrogen industry has been contributing ever increasing amounts. The nitrogenous by-products come principally from the by-product coke ovens, only 25,000 or 30,000 short tons of ammonium sulphate or the equivalent coming annually from the coal-gas plants. The quantity of ammonium sulphate or the equivalent obtained from by-product coke ovens in recent years is as follows:

Production of ammonium sulphate or equivalent from  
by-product coke ovens in the United States<sup>1</sup>

(Compiled by H. L. Bennit; short tons)

|            |         |            |         |            |                        |
|------------|---------|------------|---------|------------|------------------------|
| 1910 ..... | 81,168  | 1917 ..... | 280,396 | 1924 ..... | 544,623                |
| 1911 ..... | 88,413  | 1918 ..... | 348,654 | 1925 ..... | 639,019                |
| 1912 ..... | 107,586 | 1919 ..... | 373,223 | 1926 ..... | 690,976                |
| 1913 ..... | 148,922 | 1920 ..... | 469,463 | 1927 ..... | 717,460                |
| 1914 ..... | 143,249 | 1921 ..... | 328,501 | 1928 ..... | 798,887                |
| 1915 ..... | 172,707 | 1922 ..... | 449,233 | 1929 ..... | <sup>2</sup> / 834,306 |
| 1916 ..... | 235,265 | 1923 ..... | 575,363 |            |                        |

<sup>1</sup> 1910-1917 inclusive, figures are for sales.

<sup>2</sup> Preliminary figure.

The estimated production of nitrogen in the United States in recent years is given in the following table and is shown graphically in Figure 3:

Nitrogen production in the United States in short tons<sup>1</sup>

| Year | By-product nitrogen | Fixed nitrogen | Total nitrogen |
|------|---------------------|----------------|----------------|
| 1910 | 22,901              | 0              | 22,901         |
| 1913 | 39,330              | 0              | 39,330         |
| 1916 | 59,383              | 0              | 59,383         |
| 1919 | 86,960              | 276            | 87,236         |
| 1920 | 102,401             | 270            | 102,671        |
| 1921 | 73,501              | 200            | 73,701         |
| 1922 | 97,747              | 740            | 98,487         |
| 1923 | 139,550             | 5,910          | 145,460        |
| 1924 | 126,357             | 11,110         | 137,467        |
| 1925 | 123,600             | 13,050         | 136,650        |
| 1926 | 146,500             | 14,000         | 160,500        |
| 1927 | 152,000             | 18,000         | 170,000        |
| 1928 | 170,000             | 26,000         | 196,000        |
| 1929 | 187,600             | 84,000         | 271,600        |

<sup>1</sup> 1910-1925, inclusive, from Ernst, Fixation of Atmospheric Nitrogen, 1928.

1926-1929, inclusive, from data compiled by Fixed Nitrogen Research Laboratory.

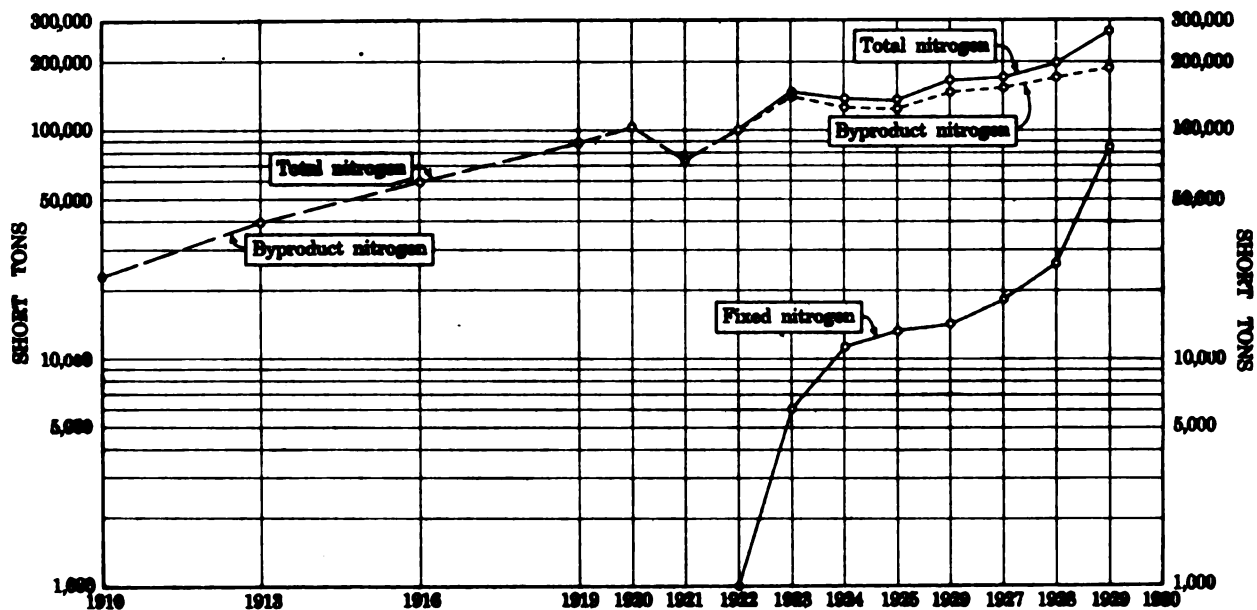


Figure 3. - Nitrogen production in the United States, short tons of nitrogen  
(Based on data from Ernst, Fixation of Atmospheric Nitrogen, and Fixed Nitrogen Research Laboratory. See tables in text)

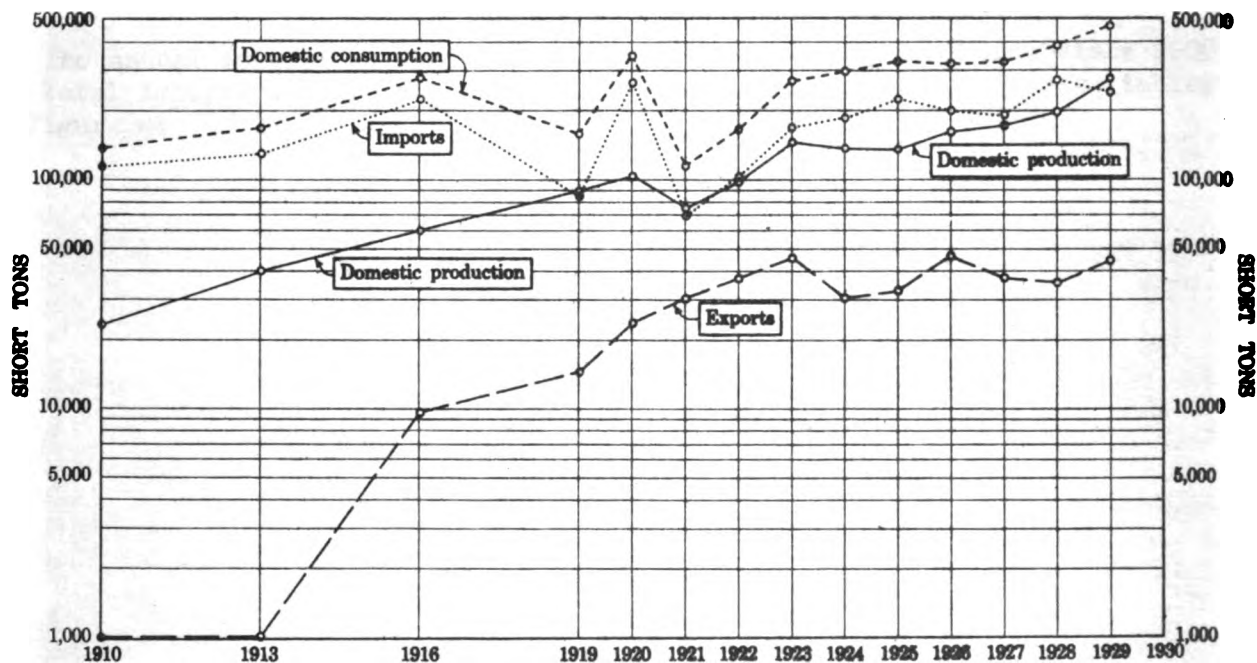


Figure 4. - Nitrogen industry of the United States, short tons of nitrogen  
(Based on tables in C. J. Brand, Recent Developments in the Fertilizer Industry, adapted from Ind. and Eng. Chem. and Chem. and Met. Eng.)

The following fixed nitrogen plants were reported to be operating in the United States at the close of 1929:

Atmospheric Nitrogen Corp., Hopewell, Va.  
Atmospheric Nitrogen Corp., Syracuse, N. Y.  
Great Western Electro-Chemical Co., Pittsburgh, Calif.  
Mathieson Alkali Works, Niagara Falls, N. Y.  
Pacific Ammonia Company, Seattle, Wash.  
Roessler & Hasslacher Chemical Co., Niagara Falls, N. Y.  
DuPont Ammonia Corp., Belle, W. Va.

Imports.— The United States is a net importer of nitrogen on a large scale. Sodium nitrate from Chile is the chief nitrogen-bearing compound imported. Calcium cyanamid ranks second and comes principally from Canada. Various organic ammoniates, such as guano from Peru, dried blood from South America, and tankage, enter in quantities of a few thousand tons each. For a few years before the World War considerable sulphate of ammonia was imported, at a maximum somewhat less than one-fifth of the total nitrogen imported, but in recent years imports of this commodity which comes chiefly from Germany have declined considerably. Other materials imported that furnish an appreciable tonnage of nitrogen are ammonium chloride largely from Germany and England, potassium nitrate from Chile, ammonium sulphate-nitrate principally from Germany, calcium nitrate chiefly from Norway and Germany, and ammonium nitrate from Norway and Germany. Numerous nitrogen-containing chemicals are imported in relatively small quantities, but in most cases these chemicals are not used primarily for their nitrogen content.

The annual imports of the principal nitrogen-bearing compounds since 1900 and the total imports in terms of pure nitrogen are shown in the following tables and in Figure 4:

Imports of principal nitrogen-bearing materials entered for consumption in the  
United States in long tons, 1900 to 1928<sup>1</sup>  
(Calendar years)

|      | Sodium<br>nitrate | Cyanamide | Sulphate<br>of<br>ammonia | Calcium<br>nitrate | Ammonium<br>nitrate | Ammonium<br>chloride | Potassium<br>nitrate |         | Ammonium<br>sulphate-<br>nitrate | Guano  | Dried<br>blood | Tannage<br>materials | Nitro-<br>genous<br>materials |
|------|-------------------|-----------|---------------------------|--------------------|---------------------|----------------------|----------------------|---------|----------------------------------|--------|----------------|----------------------|-------------------------------|
|      |                   |           |                           |                    |                     |                      | Crude                | Refined |                                  |        |                |                      |                               |
| 1900 | 182,108           | -         | 2 7,510                   | -                  | -                   | 2 2,261              | 4,708                | 2 9     | -                                | 6,620  | 2 (5)          | -                    | -                             |
| 1901 | 208,654           | -         | 2 12,934                  | -                  | -                   | 2 2,131              | 4,311                | 2 192   | -                                | 4,949  | 2 (5)          | -                    | -                             |
| 1902 | 205,245           | -         | 2 16,202                  | -                  | -                   | 2 2,987              | 4,690                | 2 93    | -                                | 3,407  | 2 (5)          | -                    | -                             |
| 1903 | 272,947           | -         | 2 14,979                  | -                  | -                   | 2 2,746              | 6,177                | 2 94    | -                                | 21,007 | 2 (5)          | -                    | -                             |
| 1904 | 228,012           | -         | 2 14,831                  | -                  | -                   | 2 3,054              | 6,332                | 2 141   | -                                | 35,876 | 2 12           | -                    | -                             |
| 1905 | 321,231           | -         | 2 13,650                  | -                  | -                   | 2 3,185              | 4,425                | 2 193   | -                                | 25,651 | 2 3            | -                    | -                             |
| 1906 | -                 | -         | 2 3,198                   | -                  | -                   | -                    | -                    | -       | -                                | -      | -              | -                    | -                             |
| 1906 | 372,222           | -         | 2 14,195                  | -                  | -                   | 2 3,958              | 5,056                | 2 69    | -                                | 22,947 | 2 (6)          | -                    | -                             |
| 1907 | 364,610           | -         | 31,447                    | -                  | -                   | 2 6,569              | 8,166                | 2 135   | -                                | 29,141 | 2 (5)          | -                    | -                             |
| 1908 | 310,713           | -         | 34,141                    | -                  | -                   | 2 3,723              | 7,196                | 2 146   | -                                | 31,469 | 2 (5)          | -                    | -                             |
| 1909 | 428,429           | -         | 38,317                    | -                  | -                   | 2 3,382              | 6,645                | 2 135   | -                                | 37,766 | 2 (5)          | -                    | -                             |
| 1910 | 529,172           | -         | 82,449                    | -                  | -                   | 2 5,613              | 5,133                | 2 1,166 | -                                | 44,268 | 2 2            | -                    | -                             |
| 1911 | -                 | -         | -                         | -                  | -                   | 2 6,228              | -                    | -       | -                                | -      | -              | -                    | -                             |
| 1911 | 544,878           | 2 5,617   | 84,494                    | -                  | -                   | 2 2,431              | 3,547                | 2 380   | -                                | 35,369 | 2 2            | -                    | -                             |
| 1912 | 436,352           | 2 7,134   | 53,163                    | -                  | -                   | 5,237                | 3,266                | 198     | -                                | 19,160 | 2 3            | -                    | -                             |
| 1913 | 625,862           | 2 14,656  | 53,201                    | -                  | -                   | 4,027                | 4,409                | 176     | -                                | 19,105 | 2 3            | -                    | -                             |
| 1914 | 541,715           | 2 29,536  | 74,121                    | -                  | -                   | 3,501                | 595                  | 163     | -                                | 25,562 | 2 (5)          | -                    | -                             |
| 1915 | 772,190           | 2 20,564  | 32,477                    | -                  | -                   | 1,135                | 57                   | 34      | -                                | 9,974  | 2 (5)          | -                    | -                             |
| 1916 | 1,218,423         | 2 38,023  | 12,962                    | -                  | -                   | 1,733                | 5,150                | 2       | -                                | 12,997 | 2 (6)          | -                    | -                             |
| 1917 | 1,543,213         | 2 44,146  | 7,263                     | -                  | -                   | 958                  | 4,115                | 283     | -                                | 6,500  | 2 (6)          | -                    | -                             |
| 1918 | -                 | 2 43,070  | -                         | -                  | -                   | -                    | -                    | 43      | -                                | -      | -              | -                    | -                             |
| 1918 | 1,910,660         | 2 45,209  | 2,893                     | -                  | -                   | -                    | 4,172                | 2       | -                                | 8,206  | 2 (6)          | -                    | -                             |
| 1919 | 407,559           | 62,121    | 2,354                     | -                  | -                   | 893                  | 16,809               | 33      | -                                | 7,017  | 4 913          | -                    | -                             |
| 1920 | 1,321,892         | 71,311    | 1,993                     | -                  | -                   | 2,991                | 16,800               | 533     | -                                | 55,790 | 6,485          | -                    | -                             |
| 1921 | 379,173           | 16,097    | 4,677                     | -                  | -                   | 2,123                | 7,403                | 593     | -                                | 1,731  | 4,457          | -                    | -                             |
| 1922 | 542,464           | 41,807    | 4,932                     | 3 1,097            | 10,701              | 3,437                | 2,438                | 458     | -                                | 13,007 | 9,162          | -                    | 3 23,484                      |
| 1923 | 891,679           | 68,532    | 3,542                     | 10,233             | 8,892               | 2,635                | 2,747                | 2,645   | -                                | 28,599 | 12,742         | -                    | 75,222                        |
| 1924 | 986,638           | 75,553    | 6,000                     | 7,682              | 1,673               | 4,346                | 639                  | 2,035   | -                                | 25,241 | 7,195          | -                    | 47,355                        |
| 1925 | 1,112,226         | 97,954    | 23,762                    | 7,777              | 4,854               | 4,906                | 3,396                | 4,134   | -                                | 17,407 | 10,189         | 321,717              | 72,790                        |
| 1926 | 914,294           | 89,728    | 8,386                     | 12,103             | 3,729               | 7,022                | 9,416                | 4,529   | 3 16,245                         | 11,673 | 11,412         | 24,568               | 55,487                        |
| 1927 | 748,782           | 109,330   | 17,153                    | 18,390             | 5,008               | 6,319                | 4,309                | 3,763   | 46,329                           | 23,321 | 11,993         | 22,002               | 53,627                        |
| 1928 | 1,032,911         | 135,727   | 37,619                    | 23,332             | 5,880               | 4,961                | 9,674                | 4,737   | 83,913                           | 22,584 | 9,511          | 43,461               | 82,611                        |

1 Data from Bureau of Foreign and Domestic Commerce publications.

2 Imports for fiscal years ended June 30.

3 Not reported separately prior to this year.

4 Figures for six months, July to December, inclusive.

5 Less than 1 ton.

6 Quantity not reported.

Total imports of nitrogen, short tons<sup>1</sup>

|            |         |            |         |
|------------|---------|------------|---------|
| 1910 ..... | 112,039 | 1923 ..... | 168,095 |
| 1913 ..... | 128,235 | 1924 ..... | 185,796 |
| 1916 ..... | 221,705 | 1925 ..... | 223,764 |
| 1919 ..... | 84,239  | 1926 ..... | 199,400 |
| 1920 ..... | 260,529 | 1927 ..... | 191,400 |
| 1921 ..... | 69,662  | 1928 ..... | 269,000 |
| 1922 ..... | 101,774 | 1929 ..... | 279,500 |

<sup>1</sup> Data from tables in C. J. Brand, Recent Developments in the Fertilizer Industry, adapted from Ind. and Eng. Chem. and Chem. and Met.

Exports.— Until recent years, as shown in the following table and in Figure 4, little inorganic nitrogen was exported from the United States. Since the World War, however, the increased production of sulphate of ammonia in the United States has given an exportable surplus of that commodity, and the reduction in the exports of sulphate of ammonia from European countries has opened certain foreign markets to the domestic sulphate of ammonia. Our exports of sulphate of ammonia, the principal nitrogen-bearing commodity exported from the United States, have under these circumstances become considerable. Considerable nitrogen is also contained in the mixed fertilizers exported, but exports of nitrogen in other forms are comparatively small.

By-product and fixed nitrogen exported from United States, short tons of nitrogen<sup>1</sup>

|            |        |            |        |
|------------|--------|------------|--------|
| 1910 ..... | 119    | 1923 ..... | 35,800 |
| 1913 ..... | 0      | 1924 ..... | 28,860 |
| 1916 ..... | 104    | 1925 ..... | 30,620 |
| 1919 ..... | 12,100 | 1926 ..... | 44,400 |
| 1920 ..... | 20,300 | 1927 ..... | 34,900 |
| 1921 ..... | 24,190 | 1928 ..... | 32,200 |
| 1922 ..... | 34,345 | 1929 ..... | 42,100 |

<sup>1</sup> Data from C. J. Brand, Recent Developments in the Fertilizer Industry, 1930.

Official records of the exports of ammonium sulphate have been kept only since May, 1920. The exports since that time are shown in the following table:

Domestic exports of ammonium sulphate, 1920 to 1929, long tons

|            |           |            |         |
|------------|-----------|------------|---------|
| 1920 ..... | 1/ 59,566 | 1925 ..... | 123,141 |
| 1921 ..... | 102,614   | 1926 ..... | 181,125 |
| 1922 ..... | 147,331   | 1927 ..... | 138,692 |
| 1923 ..... | 153,677   | 1928 ..... | 93,015  |
| 1924 ..... | 118,367   | 1929 ..... | 145,189 |

<sup>1</sup> May 1, to Dec. 31, only.

In 1929, over 95 per cent of the exports of ammonium sulphate went to four countries in the order named: Japan, Netherlands East Indies, Philippines, and Cuba. Japan took 41 per cent of the total exports.

Domestic consumption of nitrogen.— The total apparent consumption of inorganic nitrogen in the United States in 1929 as estimated by Chemical and Metallurgical Engineering (January, 1930) was 468,600 short tons. The use of natural organic nitrogen as a fertilizer, which is constantly decreasing, consumes now only about 56,000 short tons of nitrogen annually according to the National Fertilizer Association.

In 1928, general industrial uses are said to have taken about a quarter of the total apparent consumption, leaving the balance for use in fertilizers. Nitric acid manufacture, including chamber sulphuric acid plants, are said to have used 10 per cent of the total consumption of nitrogen in the United States; and the making of explosives, other than nitric acid, accounted for fully 5 per cent of the total. These two uses accounted for nearly 60 per cent of the industrial requirements for chemical nitrogen. Details regarding the nitrogen consumption for various uses in the United States are given in the following table:

Disposition of chemical nitrogen in the United States  
estimated for the calendar year 1929<sup>1</sup>

(Short tons of nitrogen contained in nitrates and ammonia compounds)

Industrial Use:

|                                                                                                                |         |
|----------------------------------------------------------------------------------------------------------------|---------|
| Nitric acid manufacture (from Chile nitrate and ammonia, including requirements for chamber acid plants) ..... | 43,000  |
| Refrigeration .....                                                                                            | 14,000  |
| Explosives (as Chile nitrate and ammonia, but excluding requirements for nitric acid manufacture) .....        | 22,500  |
| Cyanides manufacture .....                                                                                     | 9,500   |
| Soda-ash manufacture .....                                                                                     | 4,000   |
| Miscellaneous ammonium salts and nitrates .....                                                                | 4,000   |
| Aqua ammonia for miscellaneous purposes .....                                                                  | 6,000   |
| Chile nitrate for miscellaneous purposes .....                                                                 | 11,000  |
| Total nonfertilizer consumption .....                                                                          | 114,000 |

Apparent consumption in fertilizers, including increases in stocks on hand: ..... 328,000

Total apparent consumption: ..... 442,300

<sup>1</sup> Chem. and Met. Eng., vol. 36, No. 1, Page 40, Jan. 1929.

Domestic prices of nitrogen.— Although nitrogenous compounds are valued in most cases for the nitrogen they contain they are not sold on the basis of their nitrogen content. Quotations, in the case of the two principal nitrogen-bearing compounds, nitrate of soda and sulphate of ammonia, are on the basis of 100 pounds of the respective salts. In the United States there are no exchanges or otherwise officially recognized quotations on either nitrate of soda or sulphate of ammonia. The quotations that appear in the trade journals are designed to represent current spot prices in the principal markets.

The average annual prices of ammonium sulphate and sodium nitrate since the beginning of the present century taken from "The Production of Sulphate of Ammonia in 1927" by The Barrett Co., are given in the following table:

Prices of ammonium sulphate and sodium nitrate per hundred pounds

| Year | Ammonium sulphate | Sodium nitrate <sup>1</sup> | Year | Ammonium sulphate <sup>2</sup> | Sodium nitrate |
|------|-------------------|-----------------------------|------|--------------------------------|----------------|
| 1900 | \$2.87            | \$1.85                      | 1915 | \$3.30                         | \$2.38         |
| 1901 | 2.76              | 1.87                        | 1916 | 3.83                           | 3.20           |
| 1902 | 2.98              | 2.08                        | 1917 | 4.73                           | 4.11           |
| 1903 | 3.12              | 2.10                        | 1918 | 4.93                           | 4.70           |
| 1904 | 3.11              | 2.21                        | 1919 | 3.88                           | 3.57           |
| 1905 | 3.12              | 2.32                        | 1920 | 4.31                           | 3.54           |
| 1906 | 3.10              | 2.35                        | 1921 | 2.48                           | 2.45           |
| 1907 | 3.07              | 2.49                        | 1922 | 2.75                           | 2.54           |
| 1908 | 2.99              | 2.24                        | 1923 | 3.08                           | 2.52           |
| 1909 | 2.80              | 2.14                        | 1924 | 2.60                           | 2.50           |
| 1910 | 2.78              | 2.12                        | 1925 | 2.66                           | 2.59           |
| 1911 | 3.11              | 2.15                        | 1926 | 2.57                           | 2.55           |
| 1912 | 3.28              | 2.41                        | 1927 | 2.39                           | 2.51           |
| 1913 | 3.14              | 2.46                        |      |                                |                |
| 1914 | 2.71              | 2.09                        |      |                                |                |

1 Nitrate of soda quotations, f.o.b. New York; 94 per cent grade, 1900-1902; 95 per cent grade, 1903 to date. From Eng. and Min. Jour., 1900-1902, Oil, Paint and Drug Reporter, 1903 to date.

2 Ammonium sulphate quotations (25 per cent  $\text{NH}_3$ ) from Eng. and Min. Jour., 1900-1902; Oil, Paint and Drug Reporter, 1903-1916, Iron Trade Review, 1917 to date; f.o.b. producers' works, 1906 to July 16, 1925; delivered basis, July 23, 1925 to date.

In the decade prior to the outbreak of the World War in 1914 the average annual price of domestic ammonium sulphate (25 per cent  $\text{NH}_3$  = 20.56 N) ranged from \$2.78 to \$3.28 per 100 pounds. The World War started during a period of declining prices for ammonium sulphate. A short unsettled period with sharply lowered prices occurred at the opening of the war and was followed by a rise to an annual average of \$4.93 in 1918. In the case of individual sales, prices exceeded \$7.00 per hundred pounds. The cessation of hostilities was followed by a sharp decline, the average annual price dropping to \$3.88 in 1919 owing to the liquidation of war stocks of this and other forms of nitrogen. After a rapid rise to an average of \$4.31 in 1920, the price of ammonium sulphate dropped to \$2.48 in 1921. The rebound following the general business depression carried the price up to \$3.08 in 1923, but the recovery was short lived. Since 1923 the trend has been generally downward, and prices have dropped much below pre-war levels. The average price for

1928 was only \$2.28 and by June, 1930, quotations on domestic sulphate of ammonia, delivered basis, had dropped to \$1.95 in northern markets and \$2.10 in southern markets, or about 35 per cent below the 1913 average.

The average annual prices of natural sodium nitrate (95 per cent grade) in the decade preceeding the World War ranged from \$2.12 to \$2.49 per 100 pounds. Prices of this commodity had been declining for nearly two years at the opening of the World War, but unlike ammonium sulphate the low point resulting from the economic disturbances accompanying the opening of the war was not reached until the closing months of 1914. The average price rose during the war, reaching \$4.70 in 1918; it dropped to \$3.57 in 1919, and then to \$3.54 in 1920. The annual averages, however, do not show the full extent of the 1919 drop or of the subsequent rise in the post-war boom of 1920. These changes are shown by the monthly averages. The monthly average price of sodium nitrate dropped in 1919 to about \$2.90 and rose the following year to almost \$4.00. The general depression of 1921 carried the average annual price of sodium nitrate down to \$2.45 for that year. From 1921 to 1927 the price fluctuated around \$2.50 per hundred pounds (\$2.45 to \$2.59), declining to \$2.16 in 1929, which is around the pre-war level of 1909 to 1911. Prices in June, 1930, were down to \$2.07 to \$2.10, ports, for crude Chilean nitrate, whereas domestic synthetic nitrate was selling at \$1.97 to \$2.03½, ex-vessel, ports. Since 1921 the monthly average prices have shown a marked seasonal rise in the spring followed later in the year by an equally marked drop. These fluctuations were not evident in the earlier years of the period under consideration.

Previous to the World War the prices of ammonium sulphate and sodium nitrate had become so adjusted that the price of the contained nitrogen in each was practically the same. Ammonium sulphate (25 per cent  $\text{NH}_3$ ) contains 20.56 per cent of N and sodium nitrate (95 per cent grades) contains 15.66 per cent of N. The average price of ammonium sulphate was about a dollar above that of sodium nitrate in 1900, but this difference in average prices had decreased to about 70 cents in 1913. The World War introduced a change in the price relationships of these two nitrogen-bearing compounds and accordingly in the price relationships of the nitrogen content of these two salts. The differential between them became less and less and in 1927 the average price of ammonium sulphate was less than that of sodium nitrate. Since early in the war period the price of the nitrogen contained in ammonium sulphate has been consistently below the price of the nitrogen contained in sodium nitrate; in 1927, the difference, based on the average prices for the year, was about 4½ cents a pound.

Character of marketed products.— Nitrogen is marketed principally in the form of sulphate of ammonia and nitrate of soda, with smaller quantities in the form of calcium cyanamide and calcium nitrate. The balance, only about 20 per cent of the total nitrogen marketed annually, is contained in a variety of nitrogen-bearing compounds, including ammonia, ammonia liquor, various nitrates and ammonia salts, nitric acid, cyanide, sodium nitrite, and urea. Brief descriptions of the principal nitrogen-containing compounds now marketed follow.

Ammonia,  $\text{NH}_3$ , is a colorless gas containing 82.25 per cent of nitrogen and 17.75 per cent of hydrogen. It is a weak alkali, very soluble in water, and has a strong, pungent, penetrating odor.

Dry ammonia gas under pressure becomes a liquid, which is stored and shipped in steel cylinders commonly containing about 100 pounds of ammonia. It is also shipped in tank cars. If the pressure is removed, the liquid ammonia expands and vaporizes, returning to the gaseous form and absorbing a large amount of heat.

Ammonia liquor,  $\text{NH}_4\text{OH}$ , is formed when ammonia,  $\text{NH}_3$ , is absorbed in water. The solution is colorless, strongly alkaline, and unites with acids to form ammonium salts. Commercial grades of this liquor generally contain 25 to 30 per cent of ammonia,  $\text{NH}_3$ .

Ammonium nitrate,  $\text{NH}_4\text{NO}_3$ , is a white, crystalline salt containing 35 per cent of nitrogen. It is extremely soluble in water and quite hygroscopic. Under most conditions it is said that the pure salt is not explosive and can not be detonated but that long standing with tight packing may make it explosive. Mixed with combustible materials or contaminated with organic compounds it becomes much more explosive. It is difficult to handle and must be shipped in waterproof bags.

Ammonium carbonate and ammonium bicarbonate are closely related white crystalline salts, soluble in water, and with an odor of ammonia. On exposure to air the carbonate changes to bicarbonate.

Ammonium chloride,  $\text{NH}_4\text{Cl}$ , is a water-soluble crystalline salt, which is white to gray in color depending on its purity. Two technical grades, white and gray, are marketed. A U.S.P. grade is made in small quantities.

There are two commercially important ammonium phosphates: Monoammonium phosphate,  $\text{NH}_4\text{H}_2\text{PO}_4$ , and the diammonium phosphate,  $(\text{NH}_4)_2\text{HPO}_4$ . Triammonium phosphate,  $(\text{NH}_4)_3\text{PO}_4$ , is not an article of commerce on account of its instability.

Monoammonium phosphate, a white, nonhygroscopic, crystalline salt, which is soluble in water, contains about 12 per cent of nitrogen and 61 per cent of phosphoric acid. The disalt, less commercially important, contains 21 per cent of nitrogen and 53 per cent of phosphoric acid and possesses properties similar to the monosalt. It is, however, less stable.

Both monoammonium and diammonium phosphate are obtainable in chemically pure and technical grades. Commercial grades of monoammonium phosphate for fertilizer use are being produced in the United States and are marketed under the trade name of "Ammo-Phos." Two grades are produced, one containing about 10.7 per cent of nitrogen and 48 per cent of available phosphoric acid and the other, about 16.45 per cent of nitrogen and 20 per cent of available phosphoric acid. It is reported that the latter grade is a mixture of ammonium sulphate and ammonium phosphate obtained by neutralizing a mixture of phosphoric and sulphuric acids with ammonia.

A compound of diammonium phosphate and sulphate of ammonia containing about 20 per cent of nitrogen is prepared in Germany and marketed under the trade name Leunaphos. A mixture of Leunaphos and a potash salt, marketed under the name of Leunaphoska, contains 13 per cent of nitrogen.

Ammonium sulphate-nitrate is a double salt of ammonium sulphate and ammonium nitrate manufactured in Germany and Italy for fertilizer purposes and sold under the trade name of "Leunasalpeter." It contains about 26 per cent of nitrogen, about one-fourth of which is in the nitrate form and the remainder of which is ammonia nitrogen.

Calcium nitrate, or nitrate of lime,  $\text{Ca}(\text{NO}_3)_2$ , is a white, hygroscopic salt, containing, when pure, 17.1 per cent of nitrogen. Commercial calcium nitrate now on the market for fertilizer use is usually granular in form and contains about 15.5 per cent of nitrogen. Because of its hygroscopic nature, calcium nitrate must be shipped in drums or waterproof bags.

Cyanamid is the trade name for a nitrogenous fertilizer marketed in the United States containing, according to various sources of information, 45 to 70 per cent of calcium cyanamide,  $\text{CaCN}_2$ , around 25 per cent of calcium hydroxide,  $\text{Ca}(\text{OH})_2$ , and various quantities of other materials. It has a total nitrogen content of about 21 per cent. It is a black powder with a distinct alkaline reaction, the black color being due to the carbon present and the alkalinity to the large amount of lime present. Cyanamid is produced by passing a current of nitrogen gas over heated calcium carbide. The crude product is then ground, and treated with water to react with the calcium carbide and calcium oxide. The crude product ground, but without further treatment, is sold as lime-nitrogen. Treated with just enough water to destroy the carbide but not enough to slake the lime it is marketed in England as "nitrolim."

Both natural and synthetic nitrate of soda are on the world's markets, the natural nitrate of soda (Chile saltpeter) coming from Chile and the synthetic product from Europe and the United States. Pure nitrate of soda is a white, crystalline, water-soluble salt containing 16.48 per cent of nitrogen. Chilean nitrate of soda as marketed ranges from red and dull gray to pure white in color and is uniformly fine in texture. It is sold largely in two grades known as the 95 per cent and the 96 per cent grades. Premium grades of higher content and high potassium nitrate are also sold, but the controlling business is done in the first two grades mentioned. The product from one plant, in even-sized, shotlike granules, is a pure white nitrate of soda containing about 99 per cent of sodium nitrate. The 95 per cent grade, the lowest grade of Chilean nitrate marketed, contained 15.66 per cent of nitrogen.

American synthetic nitrate of soda, a fine-grained, white crystalline salt, containing 98.6 per cent of nitrate of soda, has a guaranteed nitrogen content of 16.25 per cent and a moisture content before shipping of less than 2 per cent.

Nitric acid,  $\text{HNO}_3$ , is a strong mineral acid. It is a highly corrosive liquid with strong oxidizing properties. The commercial product is sold in several standardized strengths depending upon the relative proportion of acid and water. The color of the commercial acid varies from water white to deep red.

Nitrophoska is the trade name for a series of highly concentrated complete fertilizers made in Germany. Four grades have been placed on the American market with a nitrogen content ranging from 15 to 16.5 per cent. The proportion of nitrogen in the nitrate form ranges from one-tenth to one-third of the total nitrogen content in the different grades, that in the ammonia form from nine-tenths to two-thirds. The proportions of phosphorus and potash vary in the different grades.

Potassium ammonium nitrate is prepared by the drying of an aqueous mixture of potassium chloride and ammonium nitrate. The resulting product contains about 16 per cent of nitrogen, half of which is in the nitrate form and half in the ammonia form. It also contains about 28 per cent of potash ( $K_2O$ ). This salt is prepared in Germany and marketed under the trade name Kali-ammon-salpeter for fertilizer use.

Potassium nitrate, ( $KNO_3$ , saltpeter, nitrate of potash) when pure is a neutral, colorless, crystalline, water-soluble salt containing 13.9 per cent of nitrogen. The commercial grade is a gray crystalline salt containing not less than 12 per cent of nitrogen and 44 per cent of potash ( $K_2O$ ).

Sodium nitrite is a white crystalline salt. The commercial grade contains 96 to 98 per cent of pure sodium nitrite.

Sulphate of ammonia,  $(NH_4)_2SO_4$ , when pure is an odorless, white salt, soluble in water, which contains a little over 21 per cent of nitrogen. The commercial grade varies in color from white to gray and brown and contains 20 to 21 per cent of nitrogen. The average analysis of commercial by-product sulphate of ammonia produced in the United States is said by the American Fertilizer Handbook to show 0.50 to 2.00 per cent of moisture, 20.56 to 20.80 per cent of nitrogen, and 0.10 to 0.30 per cent of free sulphuric acid. Neutral ammonium sulphate of domestic origin is also available in the markets, while nearly the whole of the output of ammonium sulphate in the United Kingdom is said to be neutral in quality. No domestic synthetic ammonium sulphate had been placed on the domestic market up to 1929. British synthetic ammonium sulphate is reported as a uniform product of white color and large crystals while the by-product ammonium sulphate of that country is of varying color and condition.

Urea is the most concentrated of the nitrogen-containing compounds.

The commercial urea for fertilizer purposes now on the market contains about 46 per cent of nitrogen; the pure compound, a white crystalline organic substance, contains 46.65 per cent. It is water soluble.

Marketing of nitrogen in the United States.— Brief notes regarding the marketing of each of the principal inorganic nitrogen compounds in the United States are given in the following paragraphs.

The market for liquid ammonia in the United States is decidedly limited, being restricted to the refrigeration industry and to certain chemical industries. It has been dominated in the past by a few ammonia companies who have used as a raw material the ammonia liquor purchased from gas and coke works, but the field has been invaded recently by the synthetic ammonia producing companies.

A number of coal-gas works producing ammonia liquor arrange with ammonia companies or dealers to take all of the liquor made, often under contracts of several years duration. Practically all of the other coal-gas works market their ammonia liquor through coal-products brokers or commission houses on contracts for periods of two or three years as a minimum.

Most of the domestic production of ammonia liquor from by-product coke-ovens is sold by a single selling agent acting on a commission basis.

A few domestic coke-oven operators market their own ammonium sulphate; but by far the greater part of the domestic production is sold on a commission basis, largely by a single company.

Most sales of ammonium sulphate are made to fertilizer manufacturers and mixers. A small quantity is sold to chemical manufacturers. Comparatively little is sold directly to fertilizer users.

Several companies import and sell Chilean nitrate of soda. Some of these own "oficinas" in the nitrate region of Chile and produce part of the nitrate which they handle, buying the rest from the Chilean Nitrate Producers Association. Others obtain all they handle from the Association. The nitrate of soda is usually shipped in cargo lots of 6,000 to 10,000 tons consigned to a single port; occasionally, however, a boat will be discharged at two or three ports. The recognized ports in the United States for the distribution of nitrate of soda are Boston, New York, Baltimore, Pensacola, Mobile, New Orleans, Norfolk, Wilmington, N.C., Savannah, Charleston, Jacksonville, and San Francisco. Hawaii is also a large consumer, cargoes going there direct. The great bulk of the business of the leading importers is done on a future basis. Their purchases frequently call for deliveries over a year or longer, and their sales often cover corresponding periods. Where nitrate of soda is handled on a commission basis a commission of 1 per cent is allowed for purchasing and a like amount for the sale. Local dealers or wholesalers may buy outright and add their own margin, or if acting for the importer they may receive up to 1 per cent commission. Some of the concerns instead of operating on a commission basis handle the trading through departments assuming all costs and overhead maintenance.

Synthetic nitrate of soda is produced by only one company in the United States, the Atmospheric Nitrogen Corporation at Hopewell, Va., a subsidiary of the Allied Chemical and Dye Co. It is marketed by The Barrett Co., another subsidiary of the Allied Chemical and Dye Co., as the Arcadian brand of nitrate of soda.

The cyanamid consumed in the United States is imported from Canada. It is produced in the plant of the American Cyanamid Co. at Niagara Falls, Ontario, the larger part of the product being shipped into the United States. Sales to the large fertilizer manufacturers, who are the principal consumers of cyanamid, are made directly by the company. Sales to consumers are also made through brokers on a commission basis.

## THE NITROGEN INDUSTRY IN PRINCIPAL FOREIGN COUNTRIES

Germany.— Germany is the only major nitrogen-consuming country besides England that is self-supporting in nitrogen. Prior to the world war Germany imported half of its nitrogen requirements in the form of sodium nitrate from Chile. The other half was produced locally, chiefly from by-product coke works, supplemented by small outputs from the then infant direct ammonia synthesis and cyanamide works. During the war and subsequently Germany has tremendously developed its synthetic nitrogen industry and is now the world's largest producer, consumer, and exporter of synthetic nitrogen; it is surpassed in exports of nitrogen only by Chile.

The production of fixed nitrogen in Germany has been estimated in the table on page 11 - at about 870,000 short tons of contained nitrogen. About 75 per cent of this production is said to be fixed by direct ammonia synthesis and 10 per cent by the cyanamide process; 11 per cent is by-product ammonia. About half of the resulting products is ammonium sulphate, 13 per cent ammonium sulphate-nitrate, 10 per cent cyanamide, 10 per cent calcium nitrate, and 4 per cent synthetic nitrate of soda.

About 75 per cent of the nitrogen production comes from the Leuna and Oppau works of the German Dye Trust (I. G. Farbenindustrie A. G.) and 10 per cent from the Government owned cyanamide plants at Piesteritz and Trostberg; 11 per cent is by-products from coke and gas plants. The Leunawerke of the I. G. company is the largest nitrogen fixation plant in the world having a capacity of 1,800 metric tons of primary nitrogen daily.

Germany's nitrogen consumption, the largest in the world, estimated at 574,300 short tons annually, is largely in agriculture, about 53 per cent of the total production being so utilized. Industry absorbs only 12 per cent of the total production, while about 35 per cent is exported.

While Germany has an annual production of nitrogen in excess of its requirements, it imports annually about 130,000 tons of Chilean nitrate of soda (20,800 tons of contained nitrogen) which is preferred in Germany for fertilizing the sugar beet crop.

Germany exports a variety of fixed nitrogen carriers; 85 per cent of the total tonnage of the nitrogen compounds exported, however, consists of ammonium sulphate and calcium nitrate.

The German Nitrogen Syndicate, organized in 1919 and renewed in 1930 for a period of seven years, includes the larger nitrogen producing companies in Germany, the I. G. Farbenindustrie A. G., Ruhrchemie A. G., Gas-Verwertungs-Gesellschaft, and the Scholven Nitrogen Works. The syndicate now represents over a million tons of nitrogen. The I. G. Farbenindustrie A. G. receives an annual sales quota of 750,000 tons of synthetic nitrogen and the Ruhr companies a quota of 251,000 tons. The firms outside of the syndicate are reported as not of outstanding importance.

**Chile.**— The natural sodium nitrate deposits of Chile, the largest known nitrate deposits in the world, lie principally in the Atacama and Tarapaca deserts of northern Chile, usually 2,500 to 3,500 feet above sea level, in desert depression along the western edge of the westward sloping plains between the high Andes Mountains on the east and the low-lying coastal ranges bordering the Pacific, 13 to 35 miles from the coast. The crude nitrate of soda (known as caliche) occurs in flat-lying beds 6 inches to 12 feet in thickness but usually only 1 to 1½ feet thick, lying beneath an overburden ranging from a few inches to 40 feet thick. The caliche is a sandy gravel, cemented with reddish-brown or bright lemon-yellow salts, and averages about 25 per cent of sodium nitrate. Some of the caliche contains considerable potassium nitrate.

Chilean nitrate sales depend entirely upon foreign markets in which Chile enjoyed a practical monopoly for many years. The World War, by stimulating the development of the synthetic nitrogen industry in many countries, caused intense competition between the natural and synthetic product, thereby placing Chilean producers definitely on the defensive. Chile still leads in international trade in nitrogen, but it now ranks second in production and contributes less than one-fourth of the world's total output of nitrogen. The period since the opening of the World War in 1914 has been marked by very erratic fluctuations in the Chilean output which in most of the post-war years has fallen below that in pre-war years. The production in 1928 and 1929, the largest in the history of the industry, was almost 20 per cent above the pre-war maximum and has resulted in the accumulation of excessive world stocks, equal on December 31, 1929, to about a year's consumption.

Statistics covering the Chilean nitrate of soda industry are given in the following table:

Statistics of Chilean nitrate of soda for the years, 1910 to 1929<sup>1</sup>

| (Metric tons)  |            |           |                   |                       |
|----------------|------------|-----------|-------------------|-----------------------|
| Calendar years | Production | Exports   | World consumption | Stocks on December 31 |
| 1910           | 2,465,415  | 2,335,941 | 2,359,652         | 1,629,454             |
| 1911           | 2,521,023  | 2,449,515 | 2,400,348         | 1,693,800             |
| 1912           | 2,585,850  | 2,493,082 | 2,529,545         | 1,619,352             |
| 1913           | 2,772,254  | 2,738,339 | 2,555,862         | 1,746,700             |
| 1914           | 2,463,356  | 1,846,783 | 2,708,968         | 3 1,185,336           |
| 1915           | 1,755,291  | 2,023,294 | 876,358           | 3 999,405             |
| 1916           | 2,912,893  | 2,980,227 | 1,451,936         | 3 845,728             |
| 1917           | 3,001,032  | 2,776,289 | 1,609,085         | 3 1,166,957           |
| 1918           | 2,859,303  | 2,919,177 | 550,966           | 3 811,992             |
| 1919           | 1,703,240  | 803,961   | 915,409           | 4 2,151,742           |
| 1920           | 2,523,458  | 2,746,118 | 1,074,599         | 4 2,112,136           |
| 1921           | 1,309,685  | 1,193,062 | 1,068,987         | 2,675,965             |
| 1922           | 1,071,041  | 1,252,050 | 1,687,926         | 1,958,129             |
| 1923           | 1,903,524  | 2,242,990 | 2,089,305         | 1,634,408             |
| 1924           | 2,406,041  | 2,333,440 | 2,330,002         | 1,721,008             |
| 1925           | 2,523,936  | 2,518,933 | 2,473,452         | 1,735,148             |
| 1926           | 2,016,400  | 1,613,731 | 1,901,952         | 1,833,725             |
| 1927           | 1,614,082  | 2,375,395 | 1,911,604         | 1,528,041             |
| 1928           | 3,162,500  | 2,132,900 | 2,525,700         | 2,133,200             |
| 1929           | 3,237,594  | 2,841,900 | 2,677,200         | 2,621,800             |

<sup>1</sup> Figures from official Chilean sources.

<sup>2</sup> Not possible to obtain figures for Europe consumption.

<sup>3</sup> Based on stocks in the United States and on the coast; data for Europe lacking.

<sup>4</sup> Stocks for the United States not available.

In the summer of 1929, to avoid a ruinous price war with the syntehtic nitrogen producers, Chile joined an international cartel which included nitrogen producers in Germany and England. Agreements were reached regarding the production and marketing of nitrogen compounds in world markets other than the United States. Reorganization of the Chilean nitrate of soda industry is also planned. A bill covering the proposed reorganization and reported to have the backing of 28 companies controlling over 91 per cent of the productive capacity of the industry has been passed by the Chilean Congress and became a law on July 21, 1930. This bill, as reported in the papers and trade journals, authorizes the formation of a company to absorb all of the existing nitrate producers. One half of the shares of the new company would be exchanged for the capital stock of existing nitrate companies, and the other half will be given to the Chilean Government in consideration of the cancellation of the whole of the export tax on nitrates. Under this bill the Chilean Government would thus become a partner with the nitrate producing companies and share with them the profit from their operations.

United Kingdom.- The United Kingdom is self-supporting in nitrogen. The annual consumption of nitrogen for all purposes in the United Kingdom is shown in the table on page 11 - to be about 76,000 short tons. The British Sulphate of Ammonia Federation, Ltd., however, has estimated that the annual consumption is about 80,000 short tons, 26,000 tons of which is used in industry.

The nitrogen compounds produced in the United Kingdom in 1928 are said to have contained 156,000 tons of nitrogen, enough to supply not only the United Kingdom but the entire British Empire's requirements for fertilizers, explosives, and all other purposes. The by-product ammonium sulphate output alone is more than sufficient for the present normal domestic requirements. Fixed nitrogen production began in the United Kingdom in 1924 with the operation of the synthetic nitrogen plant of the Synthetic Ammonia and Nitrates, Ltd. (a subsidiary of the Imperial Chemical Industries, Ltd.) at Hillingham. The reported capacity at present of this plant is placed at 2,200 tons of ammonium sulphate daily.

A variety of nitrogenous products including ammonia liquor, sulphate of ammonia, ammonium chloride, ammonium nitrate, ammonium bicarbonate, sodium nitrite, and synthetic sodium nitrate are produced in the United Kingdom, but sulphate of ammonia constitutes almost the entire amount. The total production of ammonia reported as sulphate of ammonia for the calendar year 1928 was reported by the British Sulphate of Ammonia Federation, Ltd. as 630,577 long tons, while the production of sulphate of ammonia as such for the year ending June 30, 1929, was reported as 627,000 tons.

Imports of nitrogen into the United Kingdom are chiefly Chilean nitrate with a small quantity of fixed nitrogen compounds. The annual consumption of Chilean nitrate of soda in the United Kingdom is at present 70,000 to 75,000 tons.

Exports of nitrogen from the United Kingdom are much larger than the domestic consumption and are largely in the form of sulphate of ammonia.

Most of the sulphate of ammonia producers in the United Kingdom are members of the British Sulphate of Ammonia Federation, Ltd. On July 1, 1929, this federation had 400 member companies, whose annual production for the calendar year 1928 represented about 92 per cent of the total annual output of Great Britain and Ireland. The Federation formerly carried on sales, sales promotion, propaganda, and research work, both at home and abroad for its members. During the year ending May 31, 1926, Nitram, Ltd. was formed to market forms of nitrogen other than sulphate of ammonia in cooperation with the federation. Later, Nitram, Ltd. became the sole selling agent on a nonprofit basis for the sulphate of ammonia produced by members of the federation and the sole selling agent for all of the other forms of nitrogen for agricultural consumption produced by Synthetic Ammonia and Nitrates, Ltd. Under an arrangement with the federation, Nitram Ltd. also carries on the work of agricultural research and propaganda previously conducted by the federation.

The Imperial Chemical Industries, Ltd., whose subsidiary, Synthetic Ammonia and Nitrates, Ltd., is a member of the British Sulphate of Ammonia Federation, Ltd., is a member of the international nitrogen cartel which includes fixed nitrogen producers in Germany, Norway, and Italy and the producers of natural nitrates in Chile.

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